

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS UNITED STATES AIR FORCE
WASHINGTON DC
20330-5000

SUBJECT: Engineering Technical Letter (ETL) 90-6:
Electrical System Grounding, Static Grounding and Lightning
Protection

See Distribution List

1. Attached for your information and action are criteria for the design of electrical grounding, static protection and lightning protection systems for Air Force facilities.

2. Purpose. This ETL:

a. Specifies and clarifies basic requirements for electrical grounding, static and lightning protection criteria for the design of safe and effective protection systems for Air Force facilities.

b. Supersedes those portions of referenced publications only as specifically stated.

c. Is authorized in accordance with AFR 8-7, Air Force Engineering Technical Letters (ETLs), and is to be implemented accordingly. Waivers for explosives facilities will be processed in accordance with AFR 127-100. All other waivers will be processed in accordance with the procedures established by the Model Installation Program.

3. Effective Date. This ETL is effective:

a. For all projects which have not reached the 35 percent preliminary design stage as of the date of this letter.

b. For projects, regardless of their design stage, with proposed systems which are unsafe or inadequate for acceptable equipment operation as determined by the Major Command (MAJCOM).

4. This is a coordinated HQ USAF/LEED and HQ AFESC/DEM letter. Our point of contact is Mr. Fernandez at DSN 297-4083.

CHARLES L. PEARCE, Colonel, USAF
Chief, Installation Development Division
Directorate of Engineering and Services

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ETL 90-6
3 OCTOBER 1990

ENGINEERING TECHNICAL LETTER

ELECTRICAL SYSTEM GROUNDING,
STATIC GROUNDING
AND LIGHTNING PROTECTION

Department of the Air Force
United States of America

DIRECTORATE of ENGINEERING AND SERVICES
INSTALLATION DEVELOPMENT DIVISION
ENGINEERING BRANCH

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Part 1 - General

1. Introduction. This document specifies and clarifies basic electrical grounding, static and lightning protection criteria for the most common Air Force applications. Refer to the list of publications below for additional information, definitions and for applications not covered.

2. Referenced Publications.

a. AFR 88-4, Chapter 11, Criteria for Data Processing Facility Design and Construction.

b. AFR 88-15, Criteria and Standards for Air Force Construction (Draft Version, Jan 86).

c. AFM 88-9, Chapter 3, Electrical Design, Lightning and Static Electricity Protection.

d. AFR 91-38, Maintenance of Electrical Grounding Systems.

e. AFP 91-43, Maintenance Responsibilities for Air Force Grounding Systems.

f. AFR 127-100, Explosives Safety Standards.

g. DOD 6055.9-STD, Ammunition and Explosives Safety Standards.

h. Engineering Technical Letter (ETL) 86-17, Power Conditioning and Continuation Interfacing Equipment (PCCIE).

i. Federal Information Processing Standards (FIPS) Publication 94, Guideline on Electrical Power for ADP Installations.

j. Institute of Electrical and Electronic Engineers (IEEE) Standard 141, Recommended Practice for Electrical Power Distribution for Industrial Plants.

k. IEEE Standard 142, Recommended Practice for Grounding of Industrial and Commercial Power Systems (Green Book).

l. IEEE Standard 446, Recommended Practice for Emergency and Standby Power (Orange Book).

m. Military Standard (MIL-STD) 188-124A, Grounding, Bonding and Shielding for Common Long Haul/Tactical Communication Systems.

n. Military Handbook (MIL-HDBK) 419A, Grounding, Bonding, and Shielding for Electronic Equipment and Facilities.

- o. National Fire Protection Association (NFPA) 70, National Electrical Code.
- p. Recommended Practice on Static Electricity.
- q. NFPA 78, Lightning Protection Code.
- r. USAF Handbook for the Design and Construction of HEMP/TEMPEST Shielded Facilities.

3. Definitions.

a. System Grounding. The intentional connection of a circuit conductor, such as the neutral of a generator, transformer or building service, to earth either directly (solid grounding) or through a resistance or reactance. See Figure 1.

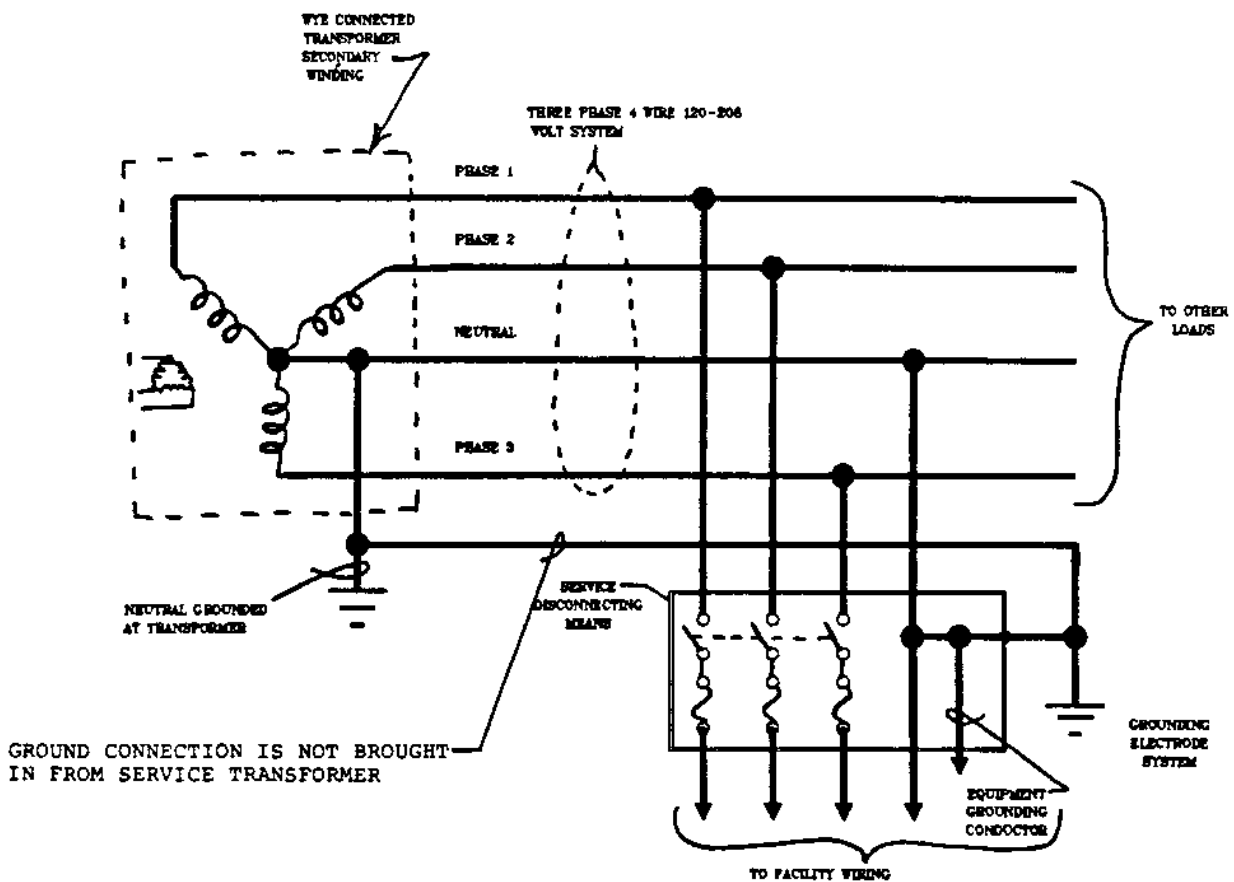


Figure 1. Typical system grounding schematic.

b. Equipment Grounding. The connection to earth of all noncurrent carrying metal parts of an electrical wiring system. See Figure 2.

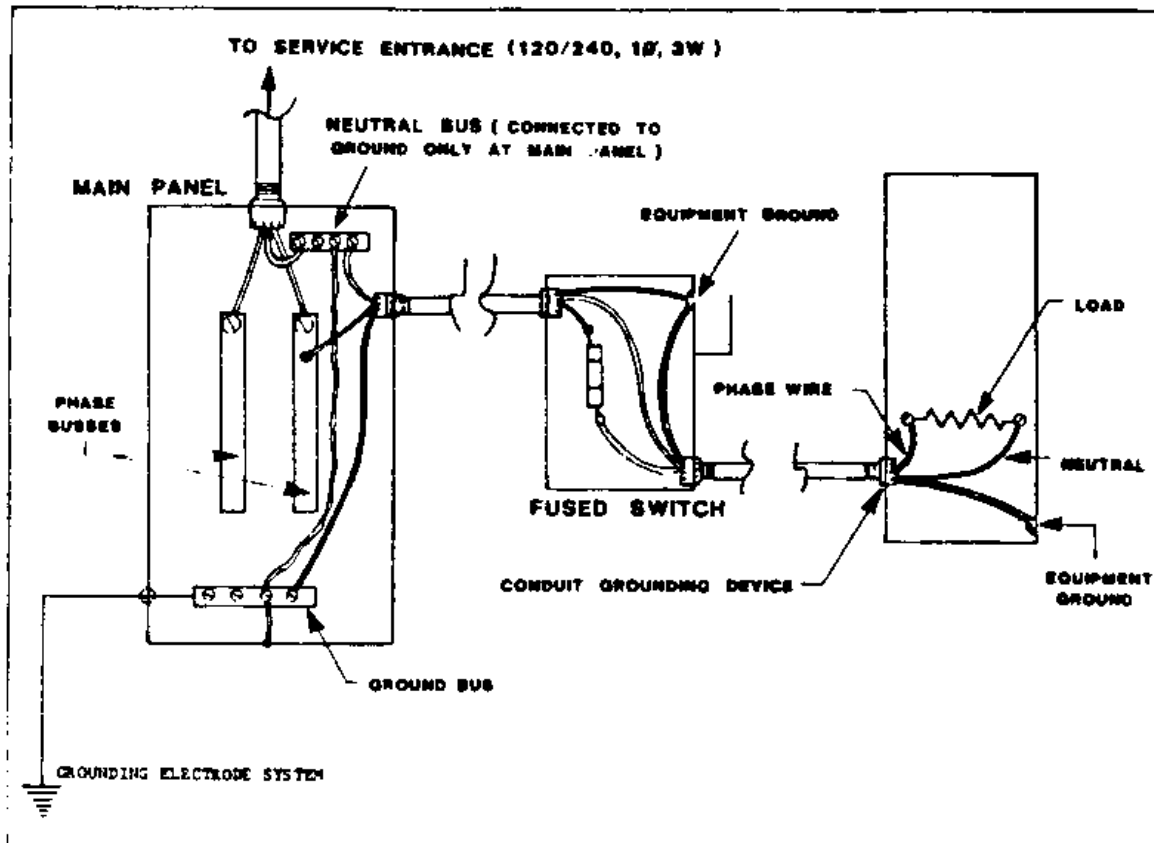


Figure 2. Typical equipment grounding schematic.
(Diagram adapted from AFP 91-38)

c. Isolated Grounding. An insulated grounding conductor which runs with the circuit conductors (including the "green wire" or equipment grounding conductor) and permitted to pass through one or more panelboards without connection to the panelboard grounding terminal and connected at the equipment grounding conductor terminal of the applicable derived system or service entrance transformer. Although not recommended except where required by the NEC, this type of grounding is sometimes used to reduce electromagnetic interference or "noise" on the ground circuit. THIS IS NOT A "SEPARATE" OR "DEDICATED" GROUNDING WHICH IS UNSAFE AND NOT PERMITTED BY THE NEC. See Figure 3.

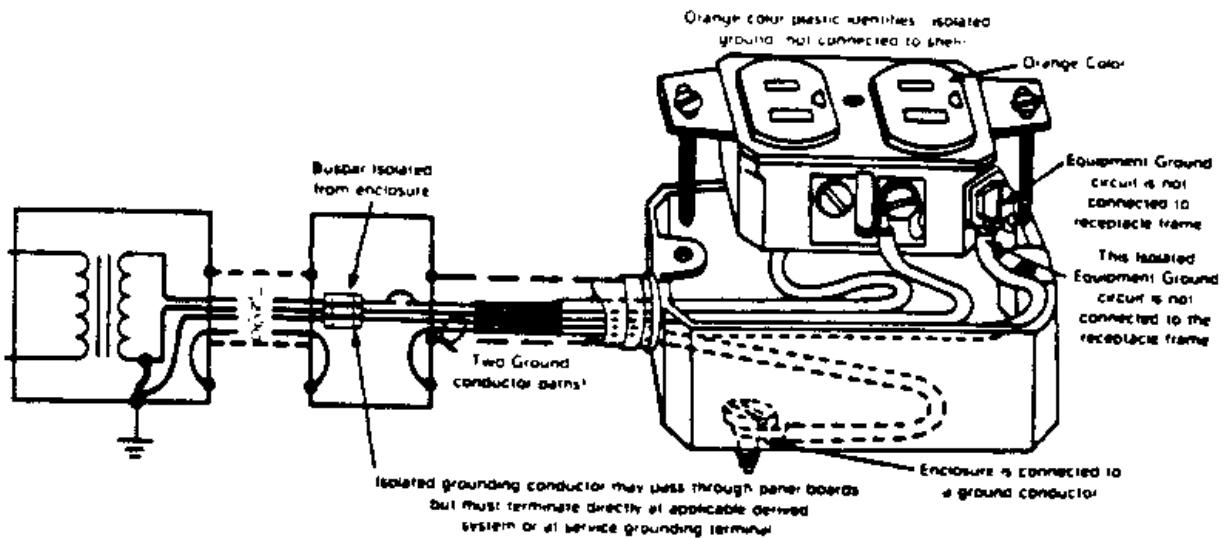


Figure 3. Typical isolated grounding schematic.
(Diagram adapted from AFR 91-38)

d. Lightning Protection Grounding. Lightning protection is required in facilities to provide a nondestructive path to ground for lightning current: to prevent dangerous side flashes between metallic objects in, on or near a facility; and to limit damaging overvoltages induced on the electrical system. Additional protection against overvoltages and surges involves the dissipation to earth of lightning induced overvoltages through arrester type devices installed at various locations within the system. See Figure 4 for typical air terminal installations to protect buildings against direct lightning strokes.

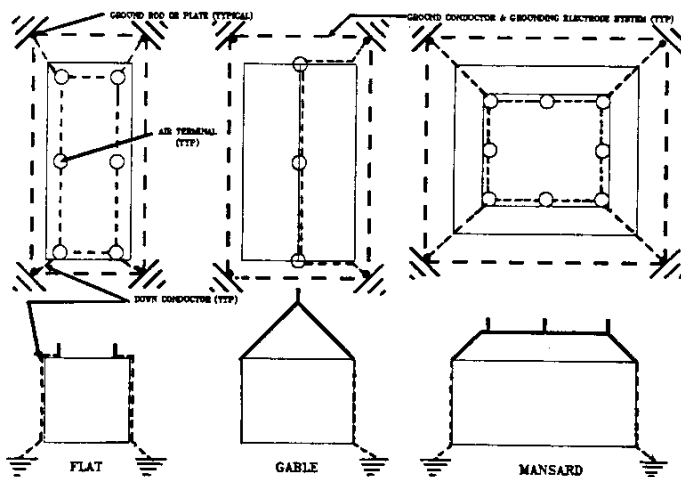


Figure 4. Lightning protection for various roof types.
(Diagram adapted from NFPA 78, Lightning Protection Code)

e. Static Grounding. Conductive paths between the-objects (bonding) and to earth (grounding) which will equalize any potential differences between them and dissipate any electrical charge. See Figure 5.

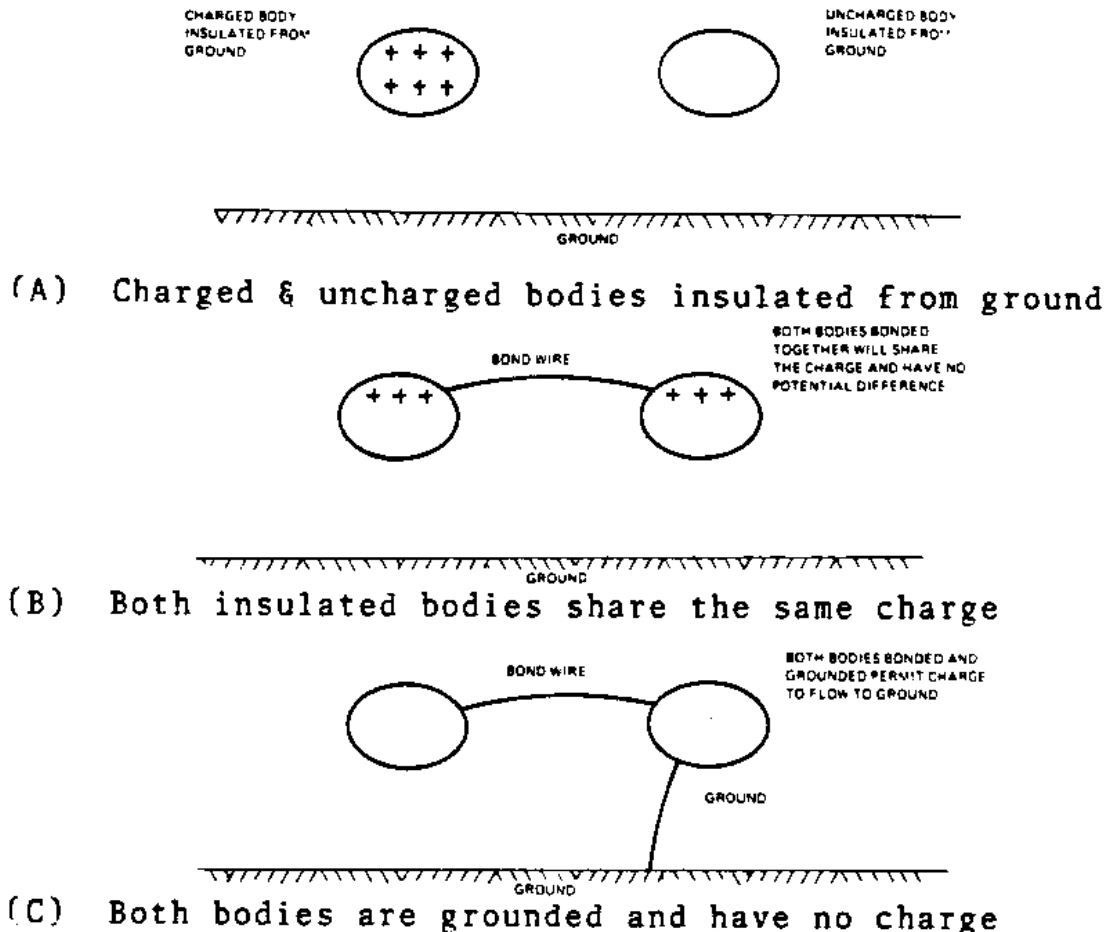


Figure 5. Static grounding of charged equipment or bodies.
(Diagrams adapted from ANSI/IEEE Std 142-1982).

f. Signal Reference Grid Grounding. Metal grid to control static charge and provide an equipotential conducting plane to which high frequency signal circuits are referenced, thereby minimizing interference and noise. This general arrangement greatly reduces the noise currents which will flow in grounded signal circuits as well as in the safety equipment ground conductors to each powered sensitive electronic equipment. It complies with code requirements and has none of the hazards of the "isolated earth electrode ground" connection. See Figure 6.

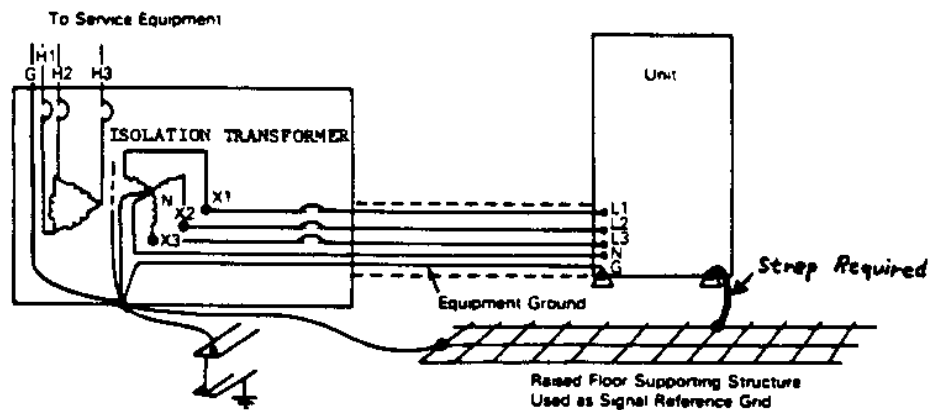


Figure 6. Typical schematic of an equipotential plane with optional ground strap recommended to reduce impulse noise currents in ADP system ground conductors.
 (Diagram adapted from FIPS Pub 94)

Optional Ground Strap in ADP System Ground Conductors]

Part 2 - Requirements

4. General Requirements. Proper electrical grounding is essential for personnel and equipment safety, as well as for satisfactory equipment operation. Improper methods and techniques can create extreme safety and fire hazards, result in personnel injury or death, and/or costly damage to the facility and its contents.

a. Facility Grounding System Functions. A safe and effective grounding system for a facility must perform a number of functions to include:

(1) System Grounding. System grounding is required for all facilities. It provides a stable system voltage reference for equipment operation; limits overvoltages caused by lightning, switching surges, ground faults and other conditions; and enables proper operation of circuit protective devices by providing a low impedance path for fault current.

(2) Equipment Grounding. Equipment grounding is required for all facilities. It eliminates the voltage shock hazard to personnel caused by unintentional contact of an energized circuit conductor with its metal frame or enclosure, and also provides a nondestructive current carrying path for fault current until it can be interrupted by a protective device.

(3) Isolated Grounding Electrodes. Connections to "separate" or "dedicated" grounding electrodes which are not bonded to the facility grounding electrode system are prohibited by the NEC.

(4) Lightning Protection Grounding. Direct stroke protection involves installing one or more air terminals (lightning rods, masts or elevated/catenary wires) designed to intercept lightning strokes, and connecting them to earth by down conductors and/or the metal building frame or skin. Reference Figure 4. Protection of explosives facilities require the protection contained in AFR 127-100 and AFR 91-43.

(5) Static Grounding. Static protection is required in facilities as described in subsequent paragraphs, typically where flammable or explosive materials are handled or processed. It prevents static electrical charges on objects such as equipment, materials and operating personnel from accumulating to a potential which can discharge from them to ground or to another charged object of different potential, creating a fire or explosion.

(6) Signal Reference Grid Grounding. Signal reference grids, which are discussed in more detail later, should generally be provided in data processing/computer room installations and

other areas where sensitive electronic equipment are installed and interconnected by high frequency signal cables. These grids must be grounded for safety, just as all other conducting members near energized electrical conductors must be grounded. At the same time, they must minimize the adverse effects of any currents which may be present on the grounding system.

b. Single System Requirement. The equipment or subsystems used to perform these functions must be integrated into a single grounding system for the facility. SO-CALLED "SEPARATE" OR "DEDICATED" GROUNDS ARE UNSAFE FOR BOTH PERSONNEL AND EQUIPMENT, AND THEIR INTENDED PURPOSE (TYPICALLY ACCEPTABLE EQUIPMENT OPERATION) CAN BE ACHIEVED BY THE SAFE AND EFFECTIVE METHODS DESCRIBED BELOW.

(1) As a minimum, all grounding electrodes, ground terminals and loop conductor/counterpoise for a facility including those used for lightning and static protection, system and equipment grounding, telephone and antenna systems, as well as the metal frames of the building and underground metal water piping, shall be bonded together in accordance with National Electrical Code (NEC) Art 250-81 to form the grounding electrode system for the facility. NOTE THAT UNDERGROUND METAL GAS PIPING MUST NOT BE USED AS A GROUNDING ELECTRODE.

(2) Bonding between other grounding media in the facility will be provided as specified by other paragraphs of this ETL and as permitted in the referenced publications. This is necessary to minimize the potential differences between noncurrent carrying metal objects within the facility which can result from lightning, ground fault and other conditions. SUCH DIFFERENCES CREATE SHOCK HAZARDS AND CAN ALSO RESULT IN DESTRUCTIVE SIDE FLASHES AND IMPROPER OPERATION OF AND DAMAGE TO EQUIPMENT.

c. Compliance with Referenced Publications. All grounding, static and lightning protection features for a facility shall comply with the applicable provisions of the references listed in Paragraph 2 of this ETL except as specifically noted.

d. Grounding and Overall Electrical System Performance. A safe and effective grounding system will preclude many electrical system performance problems, but it is not a panacea. Improper or inadequate design or installation of many other aspects of the facility's electric system can result in unacceptable equipment operation and/or hazardous conditions. Failure to provide or improper installation or application of surge arrestors, power conditioning equipment, and dedicated feeders for technical loads are just some examples of deficiencies which can cause problems often attributed to "inadequate grounding". The design, investigation

and evaluation of a facility's electrical system must, therefore, concentrate on many features of the electrical system, not just the grounding system.

5. System Grounding Requirements. The following paragraphs contain general system grounding requirements and clarifications of some specific requirements which are commonly misunderstood and violated.

a. General. Electrical systems for all facilities must be grounded in accordance with the requirements of the NEC and IEEE Standard 142 (Green Book). Solid grounding is the preferred method for low voltage (1000V or less) systems. Resistance grounding may be considered for medium voltage systems and for installations with multiple generators, where it may be necessary to limit fault current and prevent equipment damage.

b. Neutral and Ground Connections. NEC Section 250-23 requires that the grounded circuit conductor such as the neutral of a 480/277V or 208/120V electrical system must be connected to the grounding electrode system at the transformer supplying the service and at the service entrance on the supply side of the service disconnecting means. It also requires that no other grounding connection be made on the load side of the service disconnecting means except in the case of a separately derived system. This includes avoiding connections between the neutral and any grounding electrodes, equipment grounding conductors or noncurrent carrying metal parts of the wiring system. Failure to maintain this separation between neutral and "ground" throughout the facility can result in unwanted neutral return current flowing on the grounding system. THIS IS A SHOCK AND FIRE HAZARD AND CAN ALSO LEAD TO INADVERTENT OPERATION OF GROUND FAULT CIRCUIT INTERRUPTION EQUIPMENT, AND IMPROPER OPERATION OR DAMAGE TO OTHER EQUIPMENT.

c. Separately Derived Systems. A separately derived system is defined by the NEC Section 250-5 as a premises wiring system whose power is derived from a generator, transformer, or converter windings and has no direct connection, including a solidly connected grounded circuit conductor (neutral), to supply conductors in another system. The neutral of a separately derived system must be connected to a nearby grounding electrode, preferably structural metal (Section 250-26). Additionally, a bonding jumper is required between the grounded circuit conductor (neutral) and the equipment grounding conductors (metal enclosures, conduit and "green wire") of the separately derived system.

(1) Dry type transformers (isolation and non-isolation types) are common sources of separately derived systems in a facility. They are generally connected in a delta-wye configuration. To comply with the NEC and to minimize the impedance to ground, the neutral of the transformer secondary must be connected to either the nearest available, effectively grounded

structural metal member of the structure or grounded water pipe. Only when neither is available can any other grounding electrode (ground rod, counterpoise, etc) be used. Additionally, NEC Section 250-81 requires the above grounding electrode(s) to be connected to the facility grounding electrode system. THE COMMON AND WRONG PRACTICE OF ISOLATING GROUND SYSTEMS TO REDUCE ELECTRICAL NOISE ON COMPUTER SYSTEMS VIOLATES THESE ARTICLES. This will be discussed in more detail in subsequent paragraphs on signal reference grid grounding.

(2) Standby or emergency generators are also common sources of separately derived systems. However, a generator connected to a facility through a transfer switch is not a separately derived system if the neutral conductor remains connected to the normal commercial power source neutral after transfer (i.e., the neutral is not switched along with the phase conductors). In this case, the required connection of the neutral to the facility's grounding electrode system for both the commercial power source and the generator is made only on the supply side of the commercial power service disconnecting means. Providing an additional connection between the generator neutral and a grounding electrode at the generator would be a grounding connection on the load side of the service disconnecting means and a violation of the NEC. Refer to IEEE Standard 446 for additional information and requirements on grounding emergency and standby generators.

d. Grounding Electrode System Resistance. The resistance of the grounding electrode system must be low enough to ensure ground fault current can be returned to its source without creating unacceptable overvoltages on the noncurrent carrying parts of the wiring system. Additionally, the fault current must be of sufficient magnitude (particularly at locations remote from the source) to operate overcurrent devices.

(1) Low Resistance "Myth". LOW RESISTANCE GROUNDING OF ELECTRODE SYSTEMS IS DESIRABLE BUT NOT ESSENTIAL FOR A SAFE AND EFFECTIVE GROUNDING SYSTEM. In most facilities, a grounding system with a grounding electrode system of relatively high resistance can still perform properly if potential differences between the various noncurrent carrying metal objects in the facility are minimized using proper bonding techniques. LIKEWISE, A SYSTEM WITH A GROUNDING ELECTRODE SYSTEM OF VERY LOW RESISTANCE MAY STILL BE VERY UNSAFE AND INEFFECTIVE IF OTHER ASPECTS OF THE GROUNDING SYSTEM ARE IMPROPERLY DESIGNED OR INSTALLED.

(2) Basewide Applications. For standard commercial and industrial systems, IEEE Standard 142 defines an effectively grounded system (one which is adequately free from transient overvoltages) as one which is grounded through a low enough impedance such that for all system conditions, the ratio

of zero sequence reactance to positive sequence reactance (X_{U0}/X_{U1}) is positive and less than 3, and the ratio of zero sequence resistance to positive sequence reactance (R_{U0}/X_{U1}) is positive and less than 1. This ensures that line-to-ground transient voltages will be limited to 1.5 times the system (per unit) voltage. Note that proper application of this criteria requires an analysis which considers the total system reactance including that of any generators, transformers and rotating machines. It is, therefore, more appropriate for basewide systems and large industrial complexes, rather than for individual facilities. Similar criteria are also provided in the standard for resistance grounded systems.

(3) Commercial and Industrial Facilities. For most commercial and industrial facilities, the required resistance for the grounding electrode system is derived from the NEC Section 250-84 which states that a single grounding electrode consisting of a rod, pipe, or plate which does not have a resistance to ground of 25 ohms or less shall be augmented by one additional electrode. This 25 ohm value is often interpreted as the requirement for the grounding electrode system and represents a target which is easily achievable at most facilities (depending on soil conditions), particularly if other requirements for bonding together of all available grounding electrodes (Section 250-81) are met.

(4) Communication-electronics Applications. Grounding electrode systems for Communications-Electronics (C-E) facilities covered by MIL-STD 188-124 and MIL-HDBK-419 must have a maximum resistance of 10 ohms. However, this should not be interpreted as the requirement for all facilities containing electronic data processing and other electronic equipment. Design of these facilities must comply with AFR 88-4, Chapter 11, and FIPS Pub 94 as discussed in subsequent paragraphs.

(5) Hazardous Explosives Applications. AFR 127-100 contains grounding requirements for hazardous explosives facilities. To ensure adequate lightning protection, the target maximum grounding electrode system resistance is 10 ohms. The regulation specifies analyses and procedures for providing an optimum system resistance when 10 ohms or less is not achievable due to soil conditions.

(6) Other Applications. AFR 91-43 contains a table summarizing resistance requirements for grounding electrode systems at other facilities (electrical substations, aircraft parking aprons, etc).

(7) Obtaining Better Grounds. If the grounding electrode system resistance is not satisfactory and an adequate level of safety or equipment performance is not achievable due to poor soil conditions (rocky, sandy or shallow soils) after all NEC requirements have been met, an analysis

(including soil resistivity measurements) of the various methods for obtaining lower resistance such as deeper rod penetration, parallel rods, loop conductor/counterpoise, soil replacement and concrete encapsulation must be performed. THE MOST PRACTICAL AND COST EFFECTIVE METHODS WHICH WILL ENSURE AN ADEQUATE LEVEL OF SAFETY AND ACCEPTABLE EQUIPMENT PERFORMANCE MUST BE IMPLEMENTED.

e. Ground Fault Protection. NEC Section 230-95 requires ground fault protection of equipment for solidly grounded wye electrical services of more than 150V to ground, but not exceeding 600V phase to phase for each service disconnecting means rated 1000A or more. THIS IS NECESSARY TO PREVENT EQUIPMENT DAMAGE FROM HIGH IMPEDANCE (ARCING) GROUND FAULTS WHICH MAY HAVE SUFFICIENT ENERGY TO CAUSE EQUIPMENT HEATING AND BURN DOWN, BUT NOT ENOUGH CURRENT FLOW TO ACTIVATE PROTECTIVE DEVICES. However, to prevent shut down of the entire facility due to ground faults on feeders, ground fault protection with "zone isolation" features must be provided on all feeder circuits to coordinate the protection and limit the portion of the system affected. An exception to this is NEC Section 215-10: Feeder ground fault protection (GFP) is not required where GFP of equipment is provided on the supply side of the feeder.

6. Equipment Grounding Requirements. As previously stated, equipment grounding is necessary to eliminate the voltage shock hazard to personnel caused by unintentional contact of an energized circuit (phase) conductor with its metal frame or enclosure, and also provides a nondestructive current carrying path for fault current until it can be interrupted by a protective device. The NEC requirements in Art 250 must be met with the following exceptions and clarifications.

a. No Substitutes for Equipment Grounding Conductors. The noncurrent carrying metal parts of all equipment must be connected to an equipment grounding conductor system which provides an electrically continuous path for fault current to return directly to the source of the system supplying the equipment (building service or separately derived system, whichever is applicable). The earth, which is a relatively poor conductor, is not an acceptable equipment grounding conductor. Therefore, connections to nearby parts of the grounding electrode system such as structural steel or counterpoise/ground loop conductor which may be desirable for lightning protection or other purposes are permitted, BUT ARE NOT A SUBSTITUTE FOR AN EQUIPMENT GROUNDING CONDUCTOR TO THE SYSTEM SOURCE.

b. No Separate Grounds. Connections to "separate" or "dedicated" grounding electrodes which are not bonded to the facility grounding electrode system are prohibited by the NEC. This is necessary to prevent dangerous potential differences from developing during lightning and fault conditions between equipment "grounded" in this manner and any nearby metal objects

connected to other grounding electrodes. Additional information on this restriction and on the proper application and installation of "isolated" grounds is covered in the paragraphs on electronic data processing and signal reference grids.

c. Equipment Grounding Conductors. A separate, appropriately sized, "green (or bare) wire" equipment grounding conductor is required for all feeder and branch circuits in all facilities. Metallic conduit may not be used to satisfy the requirement. This paragraph superseded AFR 88-15, para 16-8 on "green wire" requirements.

7. Lightning Protection. Lightning protection systems provide for the safe dissipation of lightning strokes and surges into the earth and limit the transient overvoltages induced on the electrical system to acceptable levels. The requirements of AFM 88-9, Chapter 3, and NFPA 78 apply for standard facilities with the following clarifications and exceptions. AFR 127-100 specifies additional requirements for hazardous explosives facilities.

a. Nonconventional Systems. Only lightning protection systems recognized by the NFPA and Underwriters Laboratories may be used. Nonconventional systems such as dissipation arrays and those using radioactive lightning rods are not acceptable.

b. Manual Changes and Additions. The following additions and changes to AFM 88-9, Chapter 3 apply:

(1) Air Terminal Types. In addition to the traditional integral system of air terminals (commonly known as lightning rods), systems using overhead wires (catenaries), masts or faraday cage in accordance with NFPA 78 are acceptable. Masts and overhead wire systems have reduced maintenance requirements and afford a high level of lightning protection. Explosive facilities with perimeters over 300 feet must use a mast or overhead wire system per AFR 91-43.

(2) Hazardous Locations. Lightning protection systems for hazardous explosives facilities must comply with AFR 127-100.

(3) Terminals. Integral type air terminals must have pointed tips; capped terminals are no longer permitted. Terminals must be copper (preferred) or aluminum in accordance with NFPA 78. Use a terminal 18 inches long.

(4) Stainless steel ground rods are subject to corrosion underground and are no longer permitted.

(5) High Compression Connections. In addition to spot weld and exothermic weld type connections, high compression connections are also acceptable for grounding and bonding.

c. Bonding. Adequate bonding of metal objects and bodies in, on and near a facility to the lightning protection system is one of the most critical aspects of effective lightning protection. This ensures potential equalization and freedom from dangerous sideflashes. Chapter 3 of NFPA 78 contains details on minimum bonding requirements for ordinary facilities.

d. Ground Terminal Subsystem Resistance. NFPA 78 does not specify a maximum resistance for the ground terminal subsystem (connection of the lightning protection system to earth) for ordinary structures. However, it does require application of specific techniques such as longer and multiple ground rods and loop conductor/counterpoise to reduce the resistance in high resistivity soil conditions (sandy, gravelly or "shallow" soil). It also requires bonding of the ground terminal subsystem to other grounding media, consistent with the NEC requirement for the facility's grounding electrode system.

e. Application of Surge/Lightning Arrestors. Transient overvoltages and surges on a facility's electrical system can be produced by lightning, switching, ground faults and other conditions. Limiting these surges to an acceptable level requires proper application of surge arrestors at all levels of the electrical system, including both the interior and exterior distribution system. Arresters installed within a facility may be overwhelmed and destroyed by surges induced on incoming distribution lines if that portion of the system has not been adequately protected. As a minimum, appropriate class surge arrestors must be provided at the power transformer supplying the facility and in the facility's main distribution panel or switchgear. Additional surge protection and power conditioning may be provided by the user for his individual equipment items in accordance with ETL 86-17.

f. Spacing from Lightning Rods. NEC Section 250-46 requires at least a 6-foot clearance between lightning rod conductors and metal raceways, enclosures, frames and other noncurrent carrying metal parts of electrical equipment. Otherwise, this equipment must be bonded to the lightning rod conductors.

8. Grounding and Bonding for Static Protection. Static protection requirements in AFM 88-9, Chapter 3 and NFPA 77 apply with the exceptions and clarifications below. AFR 127-100 specifies additional requirements for hazardous explosives facilities.

a. System Integration. Bonding and grounding are common techniques for static protection. Bonding or electrically connecting two or more conductive objects equalizes the potential between the objects. Grounding minimizes the potential differences between the objects and the ground by providing a connection between them and the earth to drain off static charges before they reach a sparking potential. Although static grounds are not part of the facility's electrical power system, they must be properly integrated

into the overall facility grounding system and not applied in isolation.

b. Static Ground Resistance. All grounds used for static protection in Air Force facilities including those for aircraft and fuel tanks must have a maximum resistance of 10,000 ohms. This is in contrast to AFM 88-9, Chapter 3, which recommends maintaining an average range of between 25,000 to 100,000 ohms (resistances as high as a megohm can often provide an adequate leakage path for static electricity) to limit fault current and avoid shock hazard to personnel. Any danger of electrical shock hazard caused by the 10,000 ohm value can be eliminated by proper bonding to other grounding media (equipment grounding conductors, lightning protection system components, grounding electrode system).

c. "Exception". A specific exception to the bonding requirement of the previous paragraph involves static bus bars in hazardous explosives facilities per AFR 127-100. These static bus bars must be used only for static grounding and must not be connected to telephone grounds, electrical conduit or other nearby grounding media. However, the grounding electrodes for these bars must be bonded to the facility's grounding electrode system.

d. Conductor Size. Bonding conductors used for static protection should be #6 minimum (bare or insulated) solely for mechanical strength since static electrical currents are very small (microamps). However, any grounding conductor adequate for power circuits (sized in accordance with the NEC) or lightning protection is generally adequate for protection from static electricity.

9. Electronic Data Processing Equipment. Standard grounding techniques which are adequate for equipment operating at 60 HZ may be totally inadequate for electronic data processing equipment which may operate at clock and signal frequencies well above 10 MHZ. The underlying reason for this is the inherently high impedance of standard conductors/wires at these frequencies. In lengths greater than 1/20 of a wavelength (about 4 feet at 10 MHZ), they are very ineffective at equalizing potential and can lead to resonance conditions and electromagnetic and capacitive coupling of noise and interference onto signal circuits. Special techniques are therefore required to provide a safe and effective grounding and signal referencing system for this equipment.

a. Safety First. Acceptable performance of electronic equipment is not an excuse to violate applicable safety requirements in governing codes such as the NEC and NFPA 78. The 1990 NEC contains revisions and clarifications to specifically prohibit this.

(1) NEC Art 100 contains a revised definition of "premises wiring". Such wiring (which is subject to NEC requirements) includes all interior and exterior wiring and interconnected equipment on the load side of

the service and the output of any separately derived system (such as a transformer, generator, computer power distribution unit, or uninterruptible power supply).

(2) NEC Art 250-21 now states that currents which introduce noise or data errors in electronic equipment are not considered to be objectionable currents that allow modification of NEC grounding requirements.

b. Design and Construction Requirements. AFM 88-4, Chapter 11 contains design and construction requirements for electronic data processing facilities. By reference, it incorporates the guidelines of FIPS Pub 94 which addresses safe and effective grounding and signal referencing techniques. Communicationselectronic facilities and facilities where TEMPEST and HEMP are considerations must be designed in accordance with MIL-HDBK 419A, MIL-STD 188-124A, and the USAF Handbook for the Design and Construction of HEMP and TEMPEST Shielded Facilities, as appropriate.

c. Zero Signal Reference Grid (ZSRG). As previously stated, ZSRGs are provided in computer rooms and other facilities where electronic equipment items are interconnected by high frequency data and signal cables. They are used to control static charge and provide an equipotential conducting plane to which high frequency signal circuits are referenced, thereby minimizing interference and noise.

(1) Raised Floors. The ideal ZSRG would be a continuous sheet of material with good surface conductivity (copper, aluminum, zinc plated steel) to which all data/signal cable shields and equipment enclosures could be bonded (referenced) by very short connections. However, this is not practical from a cost and installation standpoint. Alternatives to this which exhibit acceptably low impedance at high frequencies are grids of copper wire or straps which are installed under the raised floor typically found in electronic data processing rooms. One disadvantage of these options is the increase in length of the connections from the equipment to the grid due to the height of the raised floor. This disadvantage can be overcome and costs reduced by using the raised floor itself as the ZSRG. These floors will have acceptably low impedance if they employ carefully installed bolted-down stringers and they are suitably plated with tin or zinc to permit low resistance pressure connections.

(2) Safety Connection. ZSRGs must be grounded for safety, just as all other conducting members near energized electrical conductors must be grounded. The conductor which grounds the grid at some convenient point to the equipment ground bus in a branch circuit distribution circuit breaker panel should be a green wire enclosed in conduit and of a conductor size appropriate (per the NEC) to the largest phase conductor ampacity brought into the computer room.

(3) Lightning Protection. To provide adequate protection from lightning induced overvoltages, any metal objects (structural steel, electrical and communication conduits, water pipes, air conditioning ducts, etc) passing through or near the ZSRG must be bonded to it. Also, IF BUILDING STRUCTURAL STEEL IS NOT AVAILABLE, MULTIPLE CONNECTIONS SHOULD BE MADE, if practical, between the ZSRG and the facility's grounding electrode system.

d. Isolated Ground (IG) Equipment. Certain isolated grounding techniques are permitted by the NEC. However, they should not be confused with "separate" or "dedicated" grounds which are unsafe and not permitted. Additionally, since they are of questionable value for high frequency grounding and may, during lightning conditions, exhibit potential differences between the "isolated" equipment ground and other parts (such as metal conduit and enclosures) of the facility's equipment grounding conductor system, they should be used only when required by governing codes (hospital applications) or when satisfactory equipment operation cannot be achieved by any other approved method.

(1) IG Receptacles. In IG receptacles, the grounding pin is insulated from the receptacle body and mounting yoke. Per NEC Art 250-74, this grounding pin must not be connected to any separate or dedicated ground, but must-be-connected (by an insulated conductor run with the circuit conductors) to the equipment grounding conductor terminal of the electrical source supplying the equipment (building service or first separately derived system, whichever is applicable). Additionally, the body of the receptacle (and metal outlet box and conduit) must be connected to the "green wire" facility equipment grounding conductor.

(2) Hardwired Equipment. The 1990 NEC (Art 250-75) permits the installation of an insulating spacer or fitting to interrupt the electrical continuity of a metallic raceway system at the point of connection to a metal enclosure if the metal conduit is grounded at its supply end and an equipment grounding conductor is run through the conduit into the metal enclosure and is connected to the equipment grounding terminal of the enclosure. As in the case of IG receptacles, this equipment grounding conductor must not be connected to a separate or dedicated ground, but to the equipment grounding terminal of the source supplying the equipment.

(3) Isolation Transformers. Isolation transformer must comply with the NEC requirements for separately derived systems and must not be used to establish separate or dedicated grounds for equipment. As discussed in paragraph 5c above, the neutral, enclosure (and equipment grounding conductor of the transformer's source), shield and equipment grounding conductor system of the isolation transformer must be connected to the nearest effectively

grounded structural steel or metal water pipe to minimize the impedance to ground. Any other type of grounding electrode must not be used if either is available. SEPARATE OR DEDICATED GROUNDING ELECTRODES ARE UNSAFE AND PROHIBITED BY NEC Art 250-81.

ENGINEERING TECHNICAL LETTERS (ETL)

SECTION A - CURRENT ETLs

ETL Number	Title	Date Issued
82-2	Energy Efficient Equipment	10 Nov 82
83-1	Design of Control Systems for HVAC	16 Feb 83
	Change No. 1 to ETL 83-1, U.S. Air Force Standardized Heating, Ventilating & Air Conditioning (HVAC) Control Systems	22 Jul 87
83-3	Interior Wiring Systems, AFM 88-15 Para & 7-3	2 Mar 83
83-4	EMCS Data Transmission Media (DTM) Considerations	3 Apr 83
83-7	Plumbing, AFM 88-8, Chapter 4	30 Aug 83
83-8	Use of Air-to-Air Unitary Heat Pumps	15 Sep 83
83-9	Insulation	14 Nov 83
84-2	Computer Energy Analysis	27 Mar 84
	Change 1 Ref: HQ USAF/LEEEU Msg 031600Z MAY 84	1 Jun 84
84-7	MCP Energy Conservation Investment Program (ECIP)	13 Jun 84
84-10	Air Force Building Construction and the Use of Termiticides	1 Aug 84
86-2	Energy Management and Control Systems (EMCS)	5 Feb 86
86-4	Paints and Protective Coatings	12 May 86
86-5	Fuels Use Criteria for Air Force Construction	22 May 86
86-8	Aqueous Film Forming Foam Waste Discharge Retention and Disposal	4 Jun 86
86-9	Lodging Facility Design Guide	4 Jun 86
86-10	Antiterrorism Planning and Design Guidance	13 Jun 86
86-14	Solar Applications	15 Oct 86
86-16	Direct Digital Control Heating Ventilation and Air Conditioning Systems	9 Dec 86
87-1	Lead Ban Reqmts of Drinking Water	15 Jan 87
87-2	Volatile Organic Compounds	4 Mar 87
87-4	Energy Budget Figures (EBFS) for Facilities in the Military Construction Program	13 Mar 87
87-5	Utility Meters in New and Renovated Facilities	13 Jul 87
87-9	Prewiring	21 Oct 87

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ETL Number	Title	Date Issued
88-2	Photovoltaic Applications	21 Jan 88
88-3	Design Standards for Critical Facilities	15 Jun 88
88-4	Reliability & Maintainability (R&M) Design Checklist	24 Jun 88
88-5	Cathodic Protection	2 Aug 88
88-6	Heat Distribution Systems Outside of Buildings	1 Aug 88
88-8	Chlorofluorocarbon (CFC) Limitation in Heating, Ventilating and Air-Conditioning (HVAC) Systems	4 Oct 88
88-9	Radon Reduction in New Facility Construction	7 Oct 88
88-10	Prewired Workstations Guide Specification	29 Dec 88
89-2	Standard Guidelines for Submission of Facility Operating and Maintenance Manuals	23 May 89
89-3	Facility Fire Protection Criteria for Electronic Equipment Installations	9 Jun 89
89-4	Systems Furniture Guide Specification	6 Jul 89
89-5	Air Force Interior Design Policy	not yet
89-6	Power Conditioning and Continuation Interfacing Equipment (PCCIE) in the Military Construction Program (MCP)	7 Sep 89
89-7	Design of Air Force Courtrooms	29 Sep 89
90-1	Built-Up Roof (BUR) Repair/Replacement Guide Specification	23 Jan 90
90-2	General Policy for Prewired Workstations and Systems Furniture	26 Jan 90
90-3	TEMPEST Protection for Facilities Change 1 Ref: HQ USAF/LEEDE Ltr dated 20 April 90, Same Subject	20 Apr 90
90-4	1990 Energy Prices and Discount Factors for Life-Cycle Cost Analysis	24 May 90
90-5	Fuel and Lube Oil Bulk Storage Capacity for Emergency Generators	26 Jul 90
90-6	Electrical System Grounding, Static and Lightning Protection	3 Oct 90

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SECTION B - OBSOLETE ETLs

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No.	Date	Status
82-1	10 Nov 82	Superseded by ETL 83-10, 86-1, 87-4
82-3	10 Nov 82	Superseded by ETL 83-5, 84-2
82-4	10 Nov 82	Superseded by ETL 84-7
82-5	10 Nov 82	Superseded by ETL 84-1, 86-13, 86-14
82-6	30 Dec 82	Cancel l ed
82-7	30 Nov 82	Cancel l ed
83-2	16 Feb 83	Superseded by ETL 84-3
83-6	24 May 83	Cancel l ed
84-3	21 Mar 84	Cancel l ed
84-4	10 Apr 84	Superseded by ETL 86-7, 86-159 87-5
84-5	7 May 84	Superseded by ETL 84-89 86-11, 86-18, 88-6
84-6	Not Issued	Cancel l ed/Not Used
84-9	5 Jul 84	Superseded by ETL 88-7
86-3	21 Feb 86	Superseded by ETL 86-4
86-6	3 Jun 86	Superseded by ETL 86-11, 86-18, 88-6
86-7	3 Jun 86	Superseded by ETL 86-15
86-12	3 Jul 86	Superseded by ETL 90-2
86-13	18 Aug 86	Superseded by ETL 86-14
86-15	13 Nov 86	Superseded by ETL 87-5
86-17	17 Dec 86	Superseded by ETL 89-6
86-18	18 Dec 86	Superseded by ETL 88-6
87-3	12 Mar 87	Superseded by ETL 87-6, ETL 88-5
87-6	21 Aug 87	Superseded by ETL-88-5
87-7	14 Oct 87	Superseded by ETL 89-1
Chg 1	30 Dec 87	Superseded by ETL 90-1
88-1	5 Jan 88	Superseded by ETL 89-2
88-7	24 Aug 88	Superseded by ETL 90-3 (TEMPEST Porti on)
89-1	6 Feb 89	Superseded by ETL 90-4